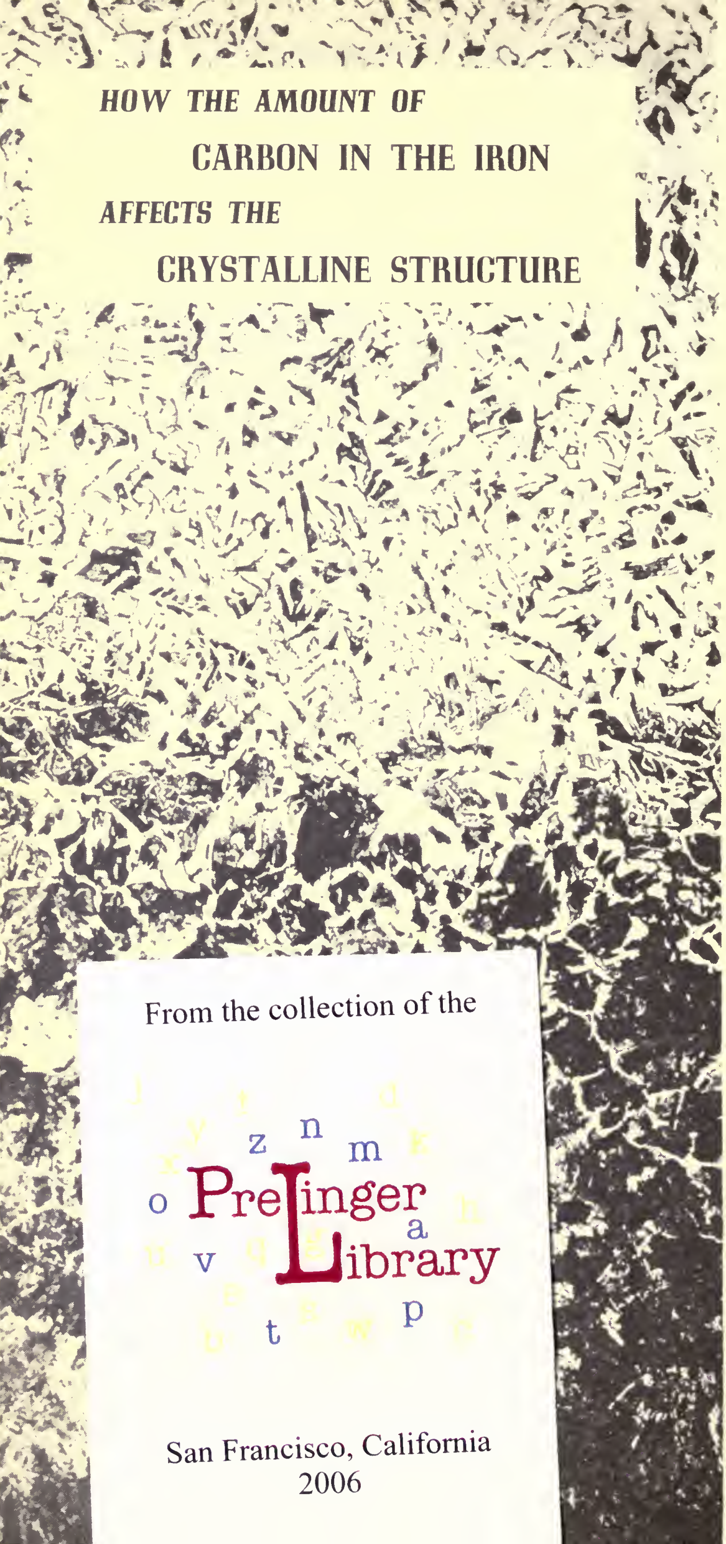
METALLURGY AND WHEELS

HOW THE AMOUNT OF CARBON IN THE IRON AFFECTS THE CRYSTALLINE STRUCTURE



STEEL
0.20% CARBON

STEEL
0.50% CARBON

STEEL
0.90% CARBON

STEEL
1.20% CARBON

METALLURGY AND WHEELS

THE STORY OF

MEN, METALS AND MOTORS

By

TECHNICAL DATA DEPARTMENT
General Motors Research Laboratories Division

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MEN, MOTORS AND METALLURGY

Reading through the General Motors' Silver Anniversary number, I ask myself how many know of the important part played by metallurgy in making possible today's automobile—a vehicle that runs 50,000 to 100,000 miles under the most trying conditions of rough handling and speed without the failure of a part? Do you know . . .

. . . That the first metallurgical laboratories for the microscopic study and control of steel, and its heat treatment, for the General Motors Corp., were put under way in 1911 by Carl Zimmerschied, later president of Chevrolet?

. . . That many of the men, now big in the industry, then laughed at us for looking at steel through a glass?

. . . That microphotos which showed the grain structure of the steel were derided as looking like the "picture of a cookie?"

. . . That when Bill Woodside told an engineer in one of the early automobile companies that he had heat treated a set of steering knuckles and arms to put in his car, the engineer said: "Nothing doing! I don't want any tempered steel in my car; I've seen enough tempered tools bust!"

. . . That the old Cadillac four-cylinder car was the first General Motors car to use alloy steel, and this was put into the transmission gears and pinions? (Because of this move, Walter Phipps was known as "one of the greatest metallurgists of the day.")

. . . That there were only two different types of alloy steel used in automobiles in the early days—and now there are more than forty?

. . . That broken axle shafts, piled room-high, and bushel baskets full of broken gears and bearings, all from the field, were common sights—and today, such types of failure are rare?

C. N. DAWE
Automotive Daily News

THE METALLURGIST AND THE AUTOMOBILE

Iron and steel have made the automobile possible. Without a widely available material capable of being easily formed and treated to obtain the special properties necessary, the automobile would still be only a curiosity.

Over four-fifths of the weight of the automobile is iron and steel. This means that the average passenger car contains about a ton and a half of iron parts. The complete car costs the owner only about 50 cents a pound for the low-priced cars and about 75 cents for the high-priced ones. A pound of sirloin steak or a pound of butter costs more than a pound of most automobiles. To accomplish this result has taken thousands of men in many kinds of work, years of patient effort. Cooperation between trained technical men and skilled workmen have produced the outstanding mechanical device of the present time—*the automobile.*

Iron Flashes

And he sang: "Hurra for my handiwork!"
And the red sparks lit the air;
Not alone for the blade was the bright steel made;
And he fashioned the first ploughshare.

Tubal Cain–
by Mackay.

Of the technical men, metallurgists have contributed some of the most important improvements to make the automobile successful. To the casual observer, these improvements are not always apparent. Many new metallurgical developments are hidden inside the engine, the transmission or the rear axle housing and are never seen except by the mechanic. Others are of such a nature that they are not readily apparent to the naked eye. To most of us one piece of iron or steel looks like another. To the metallurgist, each type of steel has its own particular use and is just as different to him as day is from night to us.

In making the automobile there are always two main considerations. One, is how shall it be made, and another is of what shall it be made. To the engineer, these are designated as problems of design and problems of materials. These two considerations are closely tied together and a knowledge of both is necessary to successfully produce the automobile. In other words, the way an automobile is made depends, to a large extent, upon the materials which are available. Improvements in mechanical design have often even had to await developments in materials.

The metallurgist has never been long in producing materials required by the engineer. Special alloys of steel have been developed to take care of many of the unusually hard requirements of the automobile and its engine. Valve materials operate for thousands of miles at red heat. Spring materials withstand millions of bumps in the road without breaking. Gear materials do not fail during the life of the car under the heavy loads which they transmit. Not the least among the metallurgist's contribu-

Iron Flashes

Iron and steel expand when heated and contract when cooled. Your automobile is over an eighth of inch longer on a hot summer day than it is on a cold day in winter.

tions is the high speed tool steel which is used to machine the various parts of the car and maintain accuracies measured in less than thousandths of an inch. Special tool steels have made large scale production of the automobile possible.

The future contributions of the automotive metallurgist will be just as important as those of the past. Even though the advancements in the past twenty-five years have been rapid, there still remain many things which can be done. A well-known metallurgist has said, "Metallurgy is one of the oldest of the arts and one of the newest of the sciences." Day after day thousands of research metallurgists painstakingly carry on their investigations to make iron and steel more useful to mankind.

POLISHING METALLURGICAL SPECIMENS

Iron Flashes

Repeated heating to red heat and cooling of cast iron will result in growth of the metal. If your engine is run without water, it gets hot enough for this growth to cause warping of the parts and sometimes spoiling them for further use.

THE METAL OF HEAVEN

Iron has been used by man for thousands of years. Today it is such a common material that we take its existence for granted. Yet the early history of iron and steel is one of the most romantic stories which could be told. Even the name by which it was called in early Egyptian writing had a poetical touch. They called iron ***ba-en-pet,*** the metal from heaven. Nearly all of the early cultured people had similar terms. The earliest Egyptian writing said that the firmament of heaven was of iron. This was because the meteors, the only things which dropped from the heavens and which they knew about, were iron.


EGYPTIAN HIEROGLYPHICS FOR IRON

The Assyrians and Babylonians used the term, ***an-bar*** or ***parzillu,*** which meant the metal of heaven. Likewise, the language of the Chaldeans and Hebrews used the term ***barsa, barsal*** or ***barzel,*** meaning the same thing.

The use of iron in Egypt can be traced back 3500 to 4000 B. C. However, it did not come into general use for another 2000 years. At one time iron was so rare that it was almost as costly as gold. In India, iron may have been used about 2000 B. C. and some historians think that the Hindoos were the first people to learn how to smelt iron from the ore. They may even have supplied the tools used to carve the hieroglyphics on the Egyptian temples, tombs and obelisks.

Iron Flashes

It has been estimated that 146,000,000 small meteorites fall on the earth each year.

Probably the first metallic iron to be used by man came from meteorites. In searching for stones to make tools and weapons, a prehistoric man may have found a meteorite. Meteorites are often composed of iron and a small amount of nickel. When he tried to chip it he found it did not break but that, by continued pounding, it could be formed into the shape he needed. Since he probably knew something of the forming of bronze and copper, he was not long in finding a way to form iron into crude tools. In this manner, man learned to recognize the importance of iron.

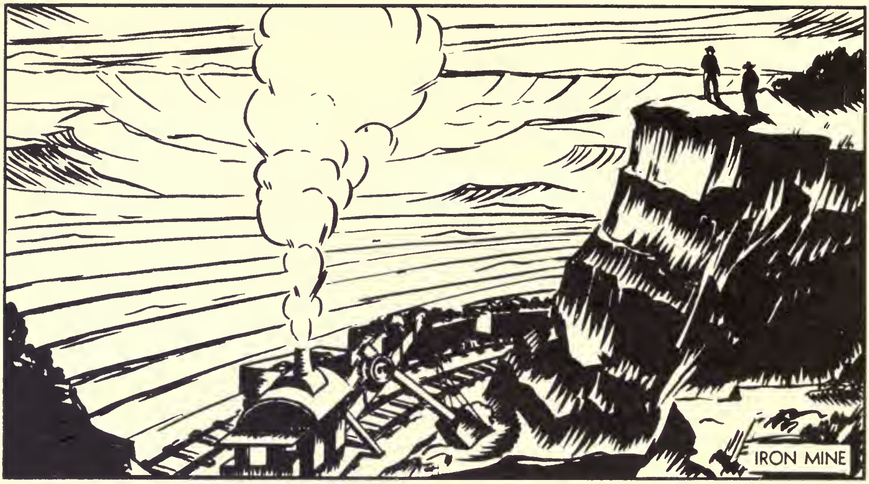
THE FOURTH MOST ABUNDANT ELEMENT

Iron is one of the most common elements. We have seen that meteorites are composed almost entirely of it. Iron is present in all natural waters; lakes, rivers, springs and the oceans. It is an important part of our bodies and the hemoglobin of the blood. The body of a man is said to contain from a quarter to a half an ounce of iron. All plants and animals similarly contain iron.

However, the iron we are most interested in from the automobile standpoint is that contained in the minerals of the earth's crust. About one-twentieth of the earth's crust is iron and it is the fourth most abundant element. Only oxygen, silicon and aluminum are

Iron Flashes

Part of an iron bracelet and dagger were found in the tomb of Tutankhamen.



present in larger amounts. Scientists tell us that the inside core of the earth is composed of almost nine-tenths solid iron. On the surface of the earth, iron is mixed with many minerals and rocks.

One of the reasons iron was not used by man from the beginning is that it seldom occurs free in nature. When iron is exposed to moist air, it combines with oxygen to form rust. Probably this is why it is not found in nature as a usable metal. If metallic iron ever existed in large quantities, it was turned to rust long before our history began. Iron ore is really a form of iron rust or iron oxide, as the chemist calls it. The raw materials for your automobile are, therefore, largely iron rust.

Iron ore is found on every continent and in almost every country. In the United States, the Lake Superior district, including Minnesota, Wisconsin and Michigan, supply most of the ore that we use today. However, iron ore is also obtained from 28 of our 48 states and has been found in all of them. The ore mined in the United States usually contains over 50 per cent iron. In some European countries the ore is used when it contains only about 25 per cent of iron.

Iron Flashes

An iron compound produces the deep blue coloring material called "Prussian Blue," sometimes used for dyeing and for laundry bluing.

FROM RUST TO IRON

We have seen that iron ore is composed of iron firmly combined with oxygen. When iron is exposed to moist air, the oxygen in the air combines with the iron to form iron rust. To obtain iron from ore we must find a way of reversing the process of rusting and remove oxygen from rust. The iron ore also has other impurities such as sulphur, phosphorus, silicon, aluminum and manganese which are not wanted in the iron.

To explain how iron is extracted from ore it is necessary to go to chemistry. Many elements combine with other elements to form new compounds. Oxygen is considered very active because it combines readily with many other elements. When it combines with hydrogen, as it does when gasoline or any petroleum oil is burned, water is formed. This is evident on cold mornings when we see steam issuing from the exhaust pipes of our automobiles. It combines with carbon in wood or coal in a furnace to form carbon dioxide. Oxygen combines more readily with some elements than with others. In the furnace it combines with coal instead of the iron sides, which shows that it would rather combine with carbon than with iron.

We use this fact in obtaining iron from iron ore. The oxygen in the ore must be taken out to leave the iron free as a metal. To do this, we heat the iron ore to a high temperature in contact with carbon in the form of coke. The carbon in the coke takes the oxygen away from the ore and leaves the iron free, since the oxygen combines more readily with carbon than with iron. The carbon and oxygen compounds which are formed,

Iron Flashes

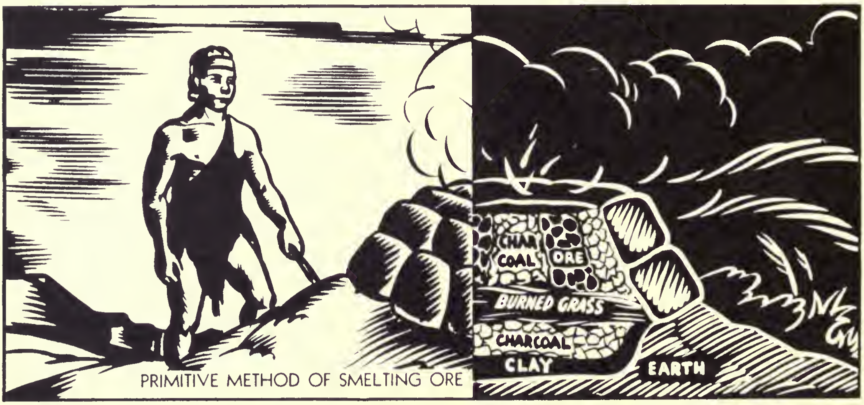
When Caesar invaded Britain he found the natives using iron bars for coins, as well as gold and copper. The iron bars were in the rough shape of a sword.

are gases which escape out of the mixture. The process must be carried out at a high temperature and so the iron is left behind in a molten state. This process is called smelting.

ANCIENT MEANS OF SMELTING ORE

While the extraction of iron from the ore did not originate in Egypt, some of the earliest records of smelting are contained on Egyptian tombs. The figure shows a metal furnace used before 1500 B. C. The draft was supplied by blowpipes and only a very small amount of metal could be melted.

Probably the earliest form of furnace was erected on high ground where a natural draft was assured. Ore and charcoal were mixed and



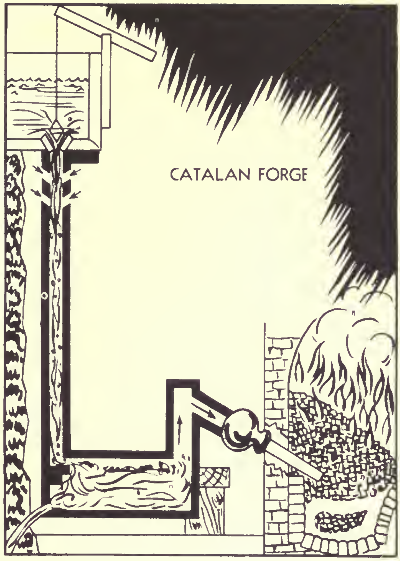
PRIMITIVE METHOD OF SMELTING ORE

the charcoal ignited. A wind would produce enough draft to form a hot fire to form crude iron and slag. As man learned more about how to use iron he built better furnaces for extracting it from the ore.

The forerunner of our modern furnaces was the Catalan forge developed in the province of Catalonia in the Northern part of Spain. It was used during the seventeenth century in Spain and Southern France. The Catalan forge was a shallow cavity made of brick or stone,

Iron Flashes

The iron pots and frying pans in the king's palace were classed among the royal jewels during the reign of King Edward III of England.



usually of an oval shape. A tube projected down through one side and into the center of the furnace through which the air entered. The ore and wood charcoal were placed in the furnace and the iron fell to the bottom as it was released from the ore. At first, air was supplied by bellows. Later, where a fall of water was available, a method of blowing the air by a water-powered blower was used. Many modifications of this furnace were introduced, later several methods of supplying a forced draft were added.

One of the greatest contributions made to the art of extracting iron from the ore was made by Dud Dudley who, in 1620, substituted coal for the wood charcoal previously used in smelting. The forests were being destroyed faster than they could be grown to supply the demand for charcoal. However, it was not until a century later that Abraham Darby substituted coke for coal and made the process a success. After that, charcoal was used only for making special types of iron.

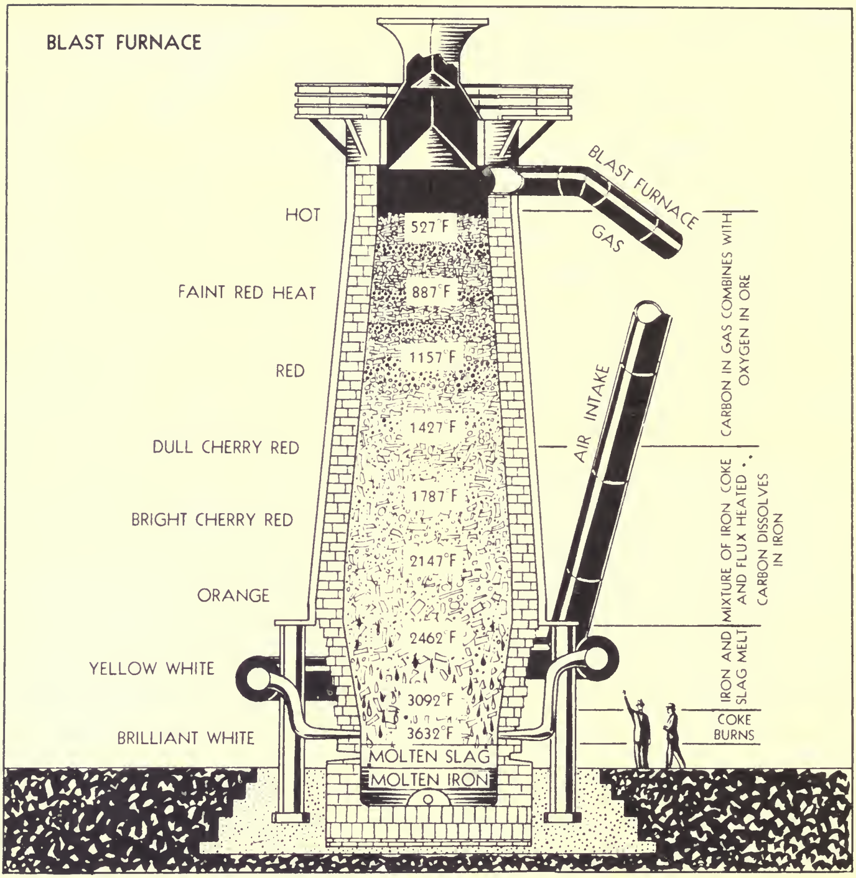
THE BLAST FURNACE

The iron made in the ancient furnaces was pasty and stiff and was not fluid. In the modern blast furnace the iron absorbs enough carbon to entirely change its nature. It is very fluid and can be cast in molds just like jelly. The ease with which cast iron can be formed in molds is one reason why it is so valuable in making complicated pieces.

The blast furnace is the modern means of extracting iron from

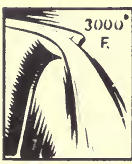
Iron Flashes

Slag is used for cement, fertilizer and road making. It is spun into rock wool and used for insulating buildings.



the ore. These are huge tubular furnaces made of steel and lined with fire brick. They may be 100 feet high and over 20 feet in diameter. The furnace has air entrances near the bottom and openings near the top to carry the gases away from the furnace.

Iron ore and coke are charged into this furnace at the top of the furnace through a chamber called a bell. Another material called a



Iron Flashes

The temperature of the molten pig iron in the blast furnace is almost 3000 degrees Fahrenheit.

flux is also necessary. Limestone is the usual flux. Marble, oyster shells and white building blocks are forms of limestone familiar to all of us.

As the coke burns, the carbon combines with the oxygen in the ore, leaving the iron behind. The carbon in the coke and oxygen in the ore combine to form gases which are released at the top of the furnace. A great amount of heat is liberated by the burning coke and the released iron melts and falls to the bottom of the furnace in a molten pool. The flux combines with some of the impurities in the ore and makes them liquid. They also fall to the bottom, but since they are lighter than iron, they float on top of the pool of iron as slag. In the process the iron combines with some of the carbon in the coke and retains some silicon, phosphorus, sulphur and manganese from the ore.

As one charge of ore, coke and limestone melts, another charge is fed from the top. The molten iron is drawn off at the bottom every few hours. The furnace operates continuously once it is started. Raw materials go in at the top and iron and slag are drawn off at the bottom. A single large furnace will make about 600 tons of iron a day or as much as there is in 400 medium size cars.

The charge must be in just the right proportions to make good iron, just as the ingredients in the batter must be in the right proportions to make a good cake. Some ores require more coke and limestone than others. The footnote below gives the average proportions of materials charged into the furnace and the products which come out.

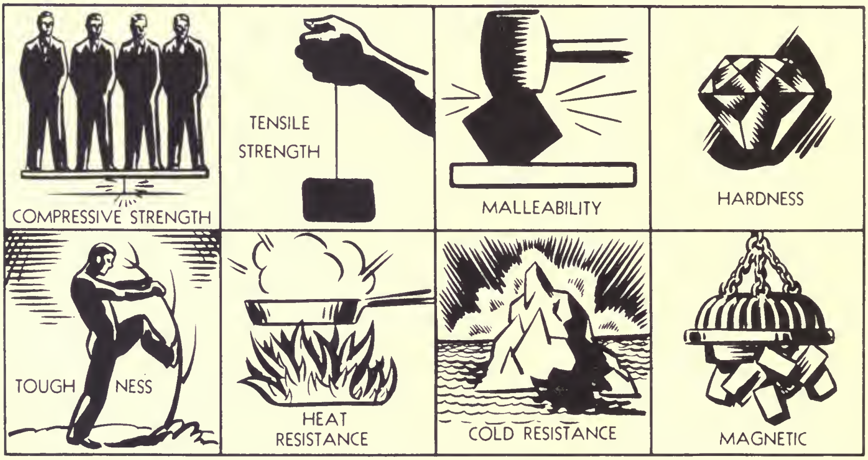
The iron which comes from the blast furnace is called pig iron. It contains 3½ to 4 per cent carbon which makes it weak and brittle, but gives it the desirable property of being fluid when heated to a high temperature. In this form it can only be used where strength is not of great importance. The pig iron is used as the raw material for making cast iron and steel.

Iron Flashes

A ton of iron ore, a half a ton of coke, 600 pounds of limestone and two and a quarter tons of air are charged into a blast furnace. This produces 1120 pounds of pig iron, 800 pounds of slag and over 3 tons of gases.

MORE IMPORTANT THAN GOLD

Steel is the most valuable form of iron. Steel can be thought of as an alloy of iron and carbon in which the carbon varies between a few hundredths of a per cent to 1.7 per cent. It may also have other materials in small quantities and still be classified as steel. The difference between steel and cast iron is in the amount of carbon which it contains. Cast iron usually contains above 1.7 per cent. The more carbon in the alloy, the more brittle is the metal. Soft steel has a few hundredths of a per cent. Hard steels may contain up to 1.7 per cent.



Steel is the most important alloy which can be hardened by suddenly cooling from a high temperature. In fact, the method once used to tell whether a material was steel or iron, was to heat it to a cherry red heat and plunge it into water. If it hardened, it was steel.

Steels are our strongest materials. The tensile strength or resistance to a pull varies from a low of 40,000 to a high of 500,000 pounds per square inch for some of the better grades of specially treated steel.

Iron Flashes

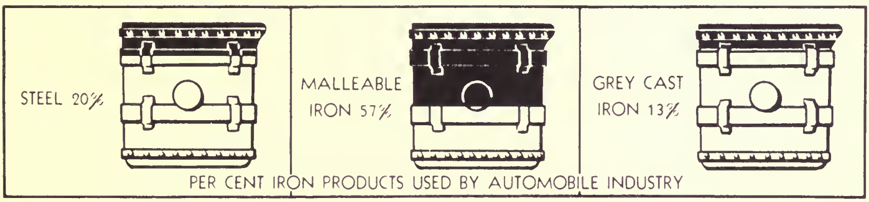
Iron pyrites, a compound of iron and sulphur with a golden yellow color, was mistaken for gold by the early prospectors. It was termed "fool's gold." Pyrites was used in ancient times to strike fire and also in wheel lock guns in place of flint.

Steels may also be made so hard they scratch glass or so soft they can be scratched with a needle. They can be given a hard surface to resist wear and a tough core to give ductility. Steels can operate over a temperature range from 250 below zero to a cherry red heat. They can be easily formed, cut, welded or bent without destroying the other properties. And for good measure, nature gave steels magnetic properties to make them valuable in electrical machinery.

Steel is more important than gold, silver, copper, tin and lead combined. We could give up any other metal with less effect upon our civilization.

THE AUTOMOBILE INDUSTRY USES ONE-FIFTH OF THE STEEL

The automobile industry is the largest single user of the steel produced in the United States. In one year over one-fifth of the steel produced was used in making automobiles. Over the past several years this has varied between 2,000,000 and 7,000,000 tons of steel of all types. In an ordinary year this figure has been about 4,000,000 tons. This is more steel than is used by the railroad, farm machinery, building, container, oil and gas, highway or machinery industries.



PER CENT IRON PRODUCTS USED BY AUTOMOBILE INDUSTRY

The automobile is also a large user of two other important forms of iron, malleable iron and cast iron. Over one-half of the malleable iron and one-seventh of the grey cast iron is used to make automobiles. In one year the industry used 245,000 tons of malleable iron and 575,000 tons of grey cast iron.

Iron Flashes

Wrought iron, a third form of the metal, contains practically no carbon. It is, therefore, very soft and pliable.

BURNING CARBON OUT OF PIG IRON

Many methods of making steel were in use prior to 1855 but none of them produced the metal in large enough quantities or at a low enough price to satisfy the demands. Pig iron or cast iron was easy to make from the ore but to get the extra carbon out of pig iron to make steel was a laborious and expensive process. The first step in making steel is to get the oxygen out of the ore to make pig iron. The second step is to get the excess carbon out of the pig iron to make steel.


BESSEMER'S FIRST CONVERTERS

The credit for devising a successful commercial process is usually given to Henry Bessemer. He was born in England of French parents in 1813. Before he became interested in iron and steel he had invented many things which had earned him the title of "the ingenious Mr. Bessemer." He devised a method of stamping deeds to prevent fraud and introduced improvements in casting and setting type. He later made considerable money on a secret process of making bronze powder.

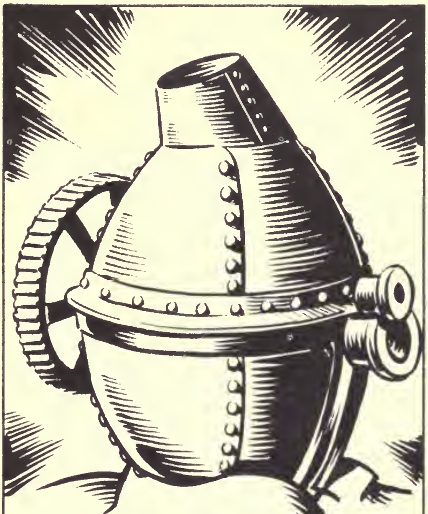
His interest in iron and steel came about after he had been called upon to aid in the development of guns and projectiles. He proposed very powerful projectiles which made the cast iron cannon then in use unsuitable. He, therefore, decided to develop a stronger material for his guns.

After several years of experimentation he found, much to his surprise, that blowing air through molten cast iron or pig iron made the iron hotter. Everyone had naturally thought that a draft of cold

Iron Flashes

Phosphorus in steel increases the brittleness and the fluidity when hot. It makes cold forming of steel difficult and is kept to a low value in such steels.

air hitting against hot iron would cool it. Encouraged by his observations he constructed a larger furnace to blow air through several hundred pounds of molten iron. The experiments were a complete success. He found that the carbon and other impurities in the iron were literally burned out of the white hot mixture by the air. The highest temperature which was at that time known to industry was produced by simply blowing air through or over fluid pig iron. He announced his discovery before a meeting of the British Association on August 11, 1856 in a paper entitled, "The Manufacture of Malleable Iron and Steel Without Fuel."



KELLY'S FIRST TILTING CONVERTER

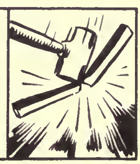
Bessemer's process was not at once a commercial success and it was not until several years later that the industry made steel by his process. When they did take it up, its success was beyond his fondest dreams. He was knighted by the king and it is said that he made a fortune of between $5,000,000 and $10,000,000.

While Bessemer reaped the benefits of his discovery of this method of making steel, the United States also has a contender for the original invention of the process. William Kelly, of Eddyville, Kentucky, also conceived of and developed a similar process. However, his customers were conservative and would have nothing to do with his new material. He continued to experiment with furnaces near his home over a period of several years.

When he heard that the United States patent office had granted Bessemer a patent in 1856, Kelly at once set out to prove that he also

Iron Flashes

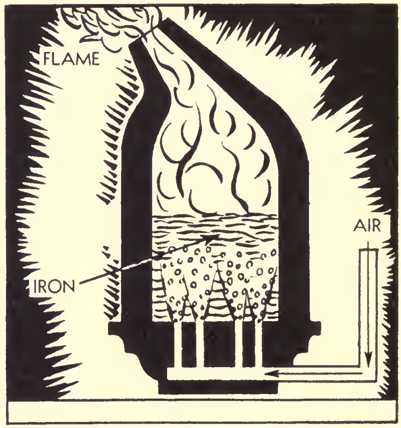
Sulphur in steel increases the brittleness to shock and makes the metal crack when it is hot. It, therefore, makes it difficult to form the steel hot as in rolling or forging, and so is kept to a low value in such steels.



was entitled to a patent. He was able to prove that he had made steel by blowing air through pig iron several years before Bessemer and obtained a patent in 1857. The American companies which were formed to operate under each of these patents, wisely decided to combine instead of fighting each other and, in 1866, this was done. Kelly never received the recognition or returns that Bessemer did, but did obtain a comfortable fortune from his interests.

BESSEMER CONVERTER

The Bessemer converter, as the furnace is called, is a large pear shaped container lined with fire brick and open at the top. It holds ten to twenty tons of cast iron. A "blow" requires 10 to 15 minutes.



Molten pig iron is poured into the furnace and a blast of air is turned on. Each ton of pig iron contains about 75 pounds of carbon, 25 pounds of silicon, one pound of sulphur, and 15 pounds of manganese, most of which will be burned out. These elements are the fuel. The molten iron is about 2200 degrees F. when it is poured in. In a few minutes after the blast of air is turned on, the burning of these

Iron Flashes

It takes a ton of iron ore, a half a ton of coke and 600 pounds of limestone to produce a half a ton of open-hearth steel.

elements in the iron raises the temperature to 3500 degrees F. Most of the carbon, silicon, sulphur and manganese are burned out which causes the mouth of the furnace to belch forth bright flames. No external fuel is necessary.

When the impurities are burned out, the correct amount of carbon and manganese is added to give the steel the final composition desired. The steel is then poured out into ingots ready to be made into shapes suitable for use.

OPEN HEARTH STEEL

After Bessemer and Kelly had led the way in making steel from pig iron, other metallurgists and scientists took up the study. Sir William Siemens developed a new type of furnace which was first used for zinc distillation and for heating iron and steel. By 1863 this furnace had been used by Martin, in France, to make steel. This method is called the Siemens-Martin Open Hearth process. At the present time more steel is made by this method than by any other process.

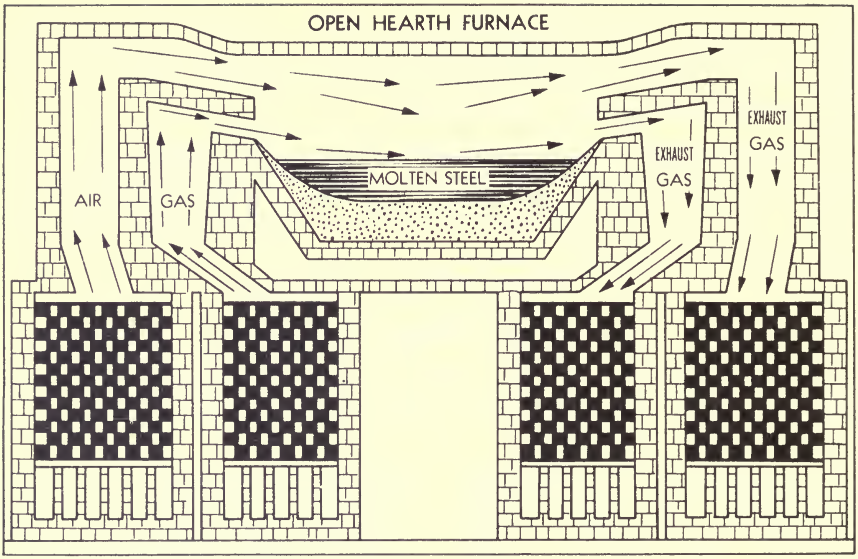
In the open hearth furnace an outside source of heat is used. The metal is contained in a large saucer-like container which holds from 5 to 250 tons of steel. Two openings at each end of the furnace admit gas and air. Underneath, and at each end of the furnace, are two chambers, one for air and one for gas, made of fire brick laid in a checkerboard pattern.

Gas rich in unburned carbon is produced in a separate furnace at one side and connected to the gas chambers by long tubes. The illustration shows a diagram of the various parts of the furnace.

In operation, the gas from the coal fire is led to one of the gas chambers. The air is pulled through one of the air chambers. The air and gas come together over the bath of molten metal which results in a high temperature. The burned gases escape from the opposite side of the furnace and pass through the second air and gas chambers,

Iron Flashes

The acid open-hearth process can only be utilized with iron low in phosphorus.



heating the brick in the chambers. Every 15 or 20 minutes, the direction of flow is reversed. The incoming air and gas are heated by being pulled through the chambers of hot brick. The temperature in the furnace is then much higher than if cold air and gas were burned over the pool of metal.

The high temperature created over the metal in the furnace aids in the process of burning out the carbon and other impurities in the iron to make steel, similar to that made in the Bessemer converter. It has the advantage that less steel is lost in the process, a better control over the alloying elements in the steel is possible, and the steel is cleaner because it contains fewer oxides. Although the open hearth process is slower, pig irons which are unsuited to the Bessemer process can be converted into steel in the open hearth furnace. Steels made by the Bessemer converter may be further refined in the open hearth furnace.

Iron Flashes

The basic open-hearth process eliminates much of the phosphorus from the steel.

ROLLING STEEL LIKE PIE CRUST

After the steel has left the furnace it is poured into upright molds and cast into ingots. The ingots are then taken to the steel mills to be made into the hundreds of commercial shapes which make the steel usable in industry. Let us examine some of the products and the processes which produce them. The automobile uses the largest percentage of strip, bar and sheet steel, as we have seen. These forms are produced in the steel mill from the white hot billets.

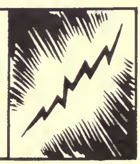
The most important process is rolling. It is fortunate that hot steel can be formed relatively easily, for it is this property of steel which makes it such a valuable material. A rolling mill works the steel ingot something like a rolling pin works pie crust. The hot steel billet is pressed between two rotating rolls and is elongated by the pressure between them. Bars, strips, plates and sheets can all be rolled in similar types of rolling mills. When special shapes are needed, such as railroad rails, building or bridge beams of I, T, H or L sections, or round or special shaped bars, special rolling mills are used. The rolls are made in the shape which it is desired to produce.

The hot steel must pass through the rolls many times for it is not possible to completely form most shapes all at once. Each pass through the rolls forms the steel a little nearer to the size and shape of the finished product. If a plate an inch or more thick is needed, only a relatively few passes through the rolls are necessary. But, if a thin plate, such as is used for automobile bodies and fenders, is desired, many passes are necessary.

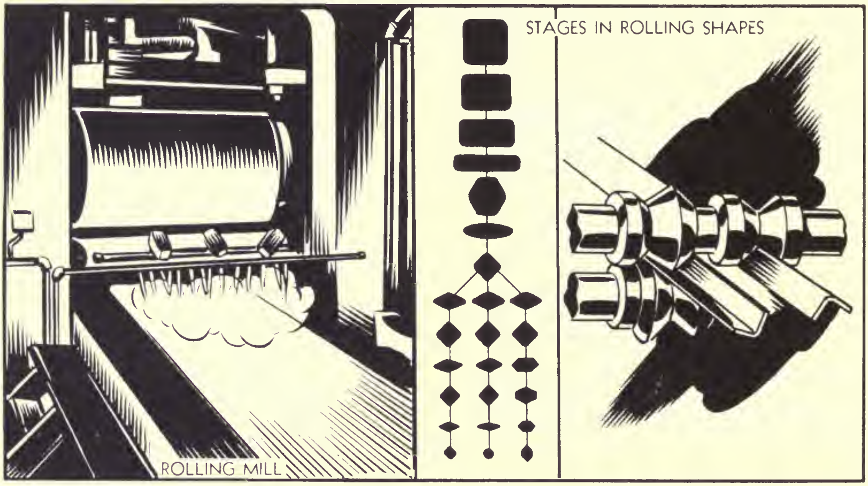
Most of these finished parts are treated before they are sold to remove scale and strains which may be set up within the material.

Iron Flashes

Steels are also made in electric furnaces. The highest quality of steel is made by the electric process because no outside impurities are introduced by a fuel and because melting conditions can be controlled better.



Various parts need different treatments, depending upon the use to which the steel is to be put. Sometimes sheets are given a pass through rolls while they are cold to smooth the surface and close the pores of the metal. Sheets are also sometimes coated with various materials, such as tin or zinc, to protect them from rusting.



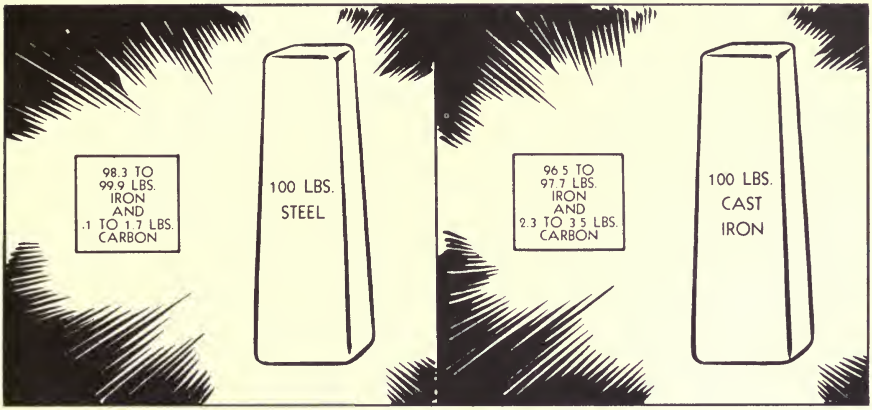
Several other common processes are used to make special products. Wire and small rods may be drawn, either hot or cold. The wire is pulled through a hole in a steel die of the correct size. Tubes and pipes are made by several methods. Welded pipe is made of a flat sheet which is bent in a round shape by drawing it through a bell-shaped die. It is then passed through welding rolls which weld the seams. Seamless steel tubing is made by piercing a round billet of the proper size and then reducing the wall thickness and diameter in suitable rolls. Smaller sizes may be made by drawing the larger tubes down to the size required. As the larger tubes are pulled out in length, the diameter of the tube is reduced.

Iron Flashes

Henry Cort, an Englishman, invented the rolling mill in 1783.

PLAIN CARBON STEELS

Carbon is the most important of all the elements which go to make up steel. Carbon is familiar to all of us in many forms. Coal, lampblack and the diamond contain large quantities of carbon. It is a part of all living matter both plant and animal. The sun and stars owe much of their brilliance to clouds of incandescent carbon, thousands of miles deep, which encircle them.

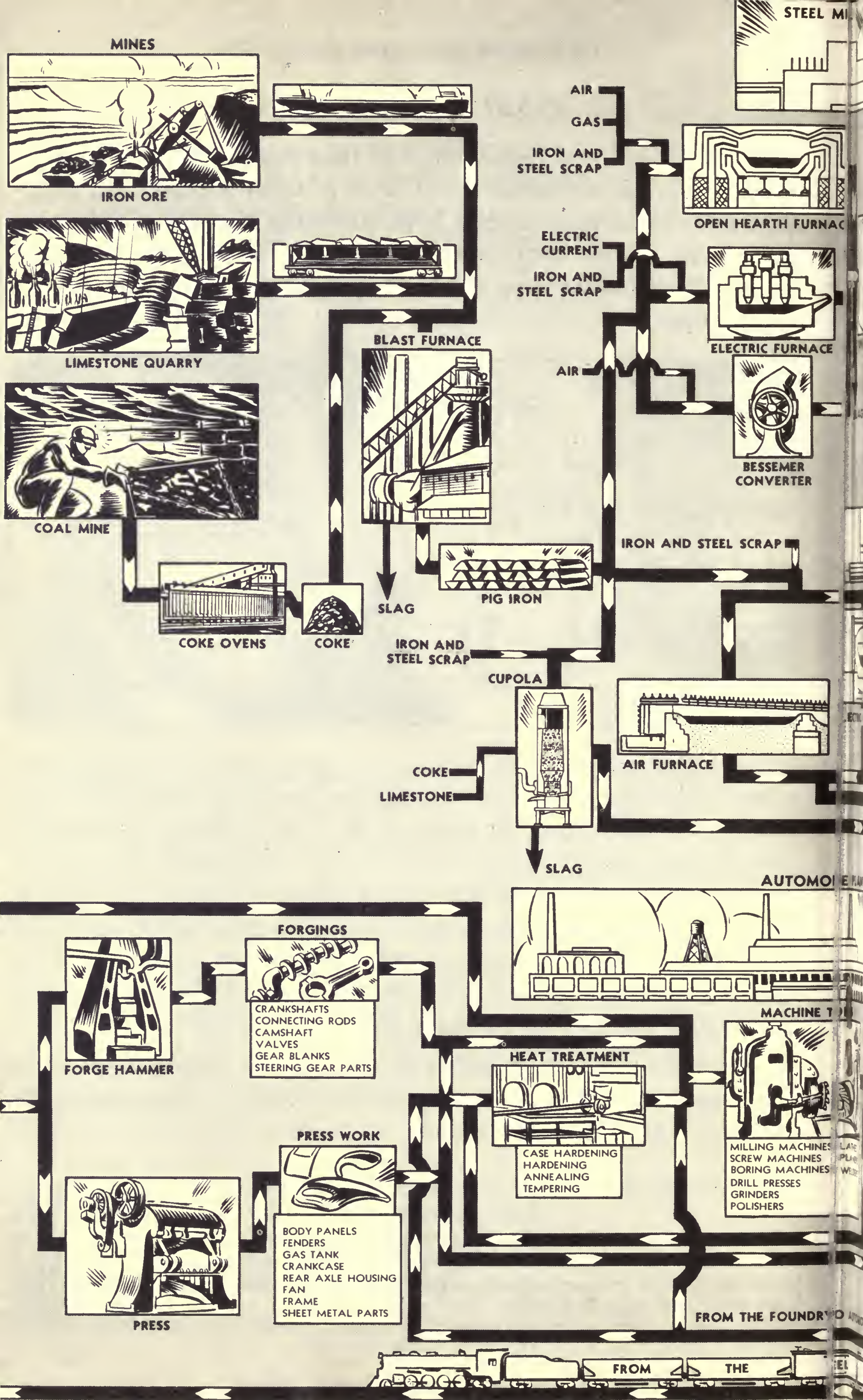


As we have seen, steels contain carbon in amounts varying from a few hundredths of a per cent to 1.7 per cent. In general, increasing the amount of carbon in the steel, increases the hardness of the metal. Low carbon steels, those with up to ¼ per cent carbon, are soft and can be easily bent and formed even when cold. They are, therefore, much used for making sheet metal and other parts which must be formed into complicated shapes and which do not need to be very hard. Body panels, frames, fenders, gas tanks, radiator shells and many small pressed steel parts are made of low carbon steel.

Medium carbon steels are much stronger than low carbon steels and their strength may be greatly increased by heat treatments. The percentage of carbon varies from $\frac{3}{10}$ to ½ a per cent in medium

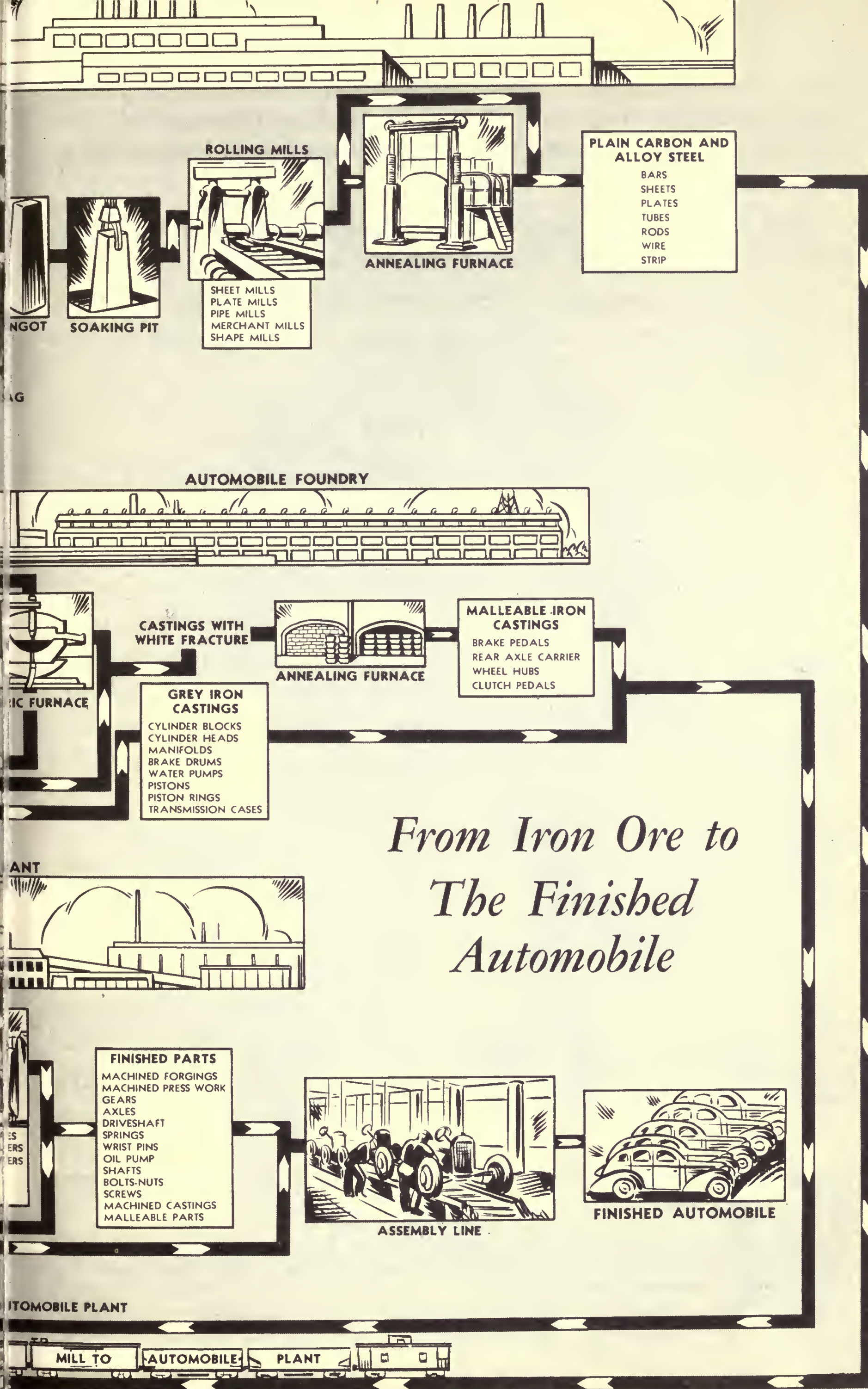
Iron Flashes

Steel does not break by crystallization. Steel is always made up of crystals. It breaks by fatigue. Repeated bending slips these crystals over each other until microscopic cracks are finally opened up. These fine cracks weaken the metal until it finally breaks.



LARGE COPIES OF THIS CHART WILL

From Iron Ore to The Finished Automobile



ED TO SCHOOLS UPON REQUEST

carbon steels. Small and medium sized forged parts such as connecting rods, crankshafts, and camshafts are made of medium carbon steel. Axle shafts, propeller shafts, and transmission shafts are also made of these steels.

High carbon steels containing up to one per cent carbon are used for springs, bumper bars, valve springs and leaf springs.

Steels with the highest percentage of carbon are very hard and fine grained. They are used for tools where alloy tool steels are not necessary.

ALLOY STEELS

In the manufacture of steel by the Bessemer, open hearth or electric furnace, small amounts of other metals are sometimes added to change the properties of the steel. The Society of Automotive Engineers lists about seventy different kinds of steel which are used in automobile construction. To the metallurgist, steels with small quantities of elements other than carbon, phosphorus, sulphur, and silicon are known as alloy steels. Even small quantities of some materials, sometimes only one or two parts in 1000, will produce great changes in the finished product.

The automobile industry is the largest user of alloy steels and uses over five-eighths of all the alloy steels produced.

Iron Flashes

Hardness of steel is determined by forcing a hard steel ball or a diamond into the metal with a uniform pressure. The size of the indentation is a measure of the hardness.

MANGANESE

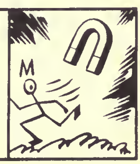
Manganese was known from ancient times although it was not used in any practical manner. The first use of manganese was in glass making where it was used to bleach glass to a crystalline clearness. Larger amounts were used to produce violet, red and dark brown colored glass in early times. The color of the amethyst is due to small quantities of iron and manganese which it contains.

STAINED GLASS WINDOW—12TH CENTURY

Today, by far the largest amount of manganese is used in making steel and all steel contains small amounts of it. In small percentages it is used to deoxidize the steel thus aiding in producing a clean metal. In amounts over 4 parts in 1000 it definitely affects the properties as a result of heat treatment. In amounts of 11 to 12 per cent it makes an extremely abrasion-resisting steel much used for wearing parts of machinery. It is so hard that after it is cast, it cannot be cut and must be ground. Because it is so hard that it cannot be drilled or cut, it is much used for burglarproof safes, steam shovel buckets and various types of crushing machinery.

Iron Flashes

Manganese steel is practically nonmagnetic, even though it contains over 85 per cent of iron.



SILICON

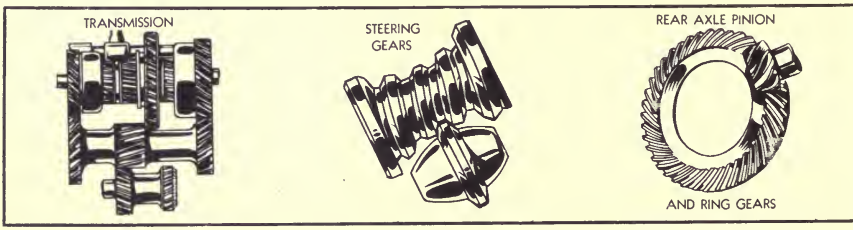
Silicon is the second most abundant element on the earth's crust. Combined with oxygen and other elements, it forms sand, quartz, amethyst, agate, opal and flint. Crystalline silicon is in form of black needles harder than glass. In combination with carbon it forms carborundum used for making grinding wheels.

Silicon in amounts up to .03 per cent is used chiefly for deoxidizing steel. It is used to reduce the oxygen content lower than can be done with manganese. Steels with two per cent silicon and a small amount of manganese are sometimes used for automobile leaf springs. In such amounts silicon acts as an alloy and confers greater strength.

NICKEL

Nickel is common to everyone in nickel plated parts and as an alloying element in our five-cent piece. It is found, along with iron, in many meteorites. Most of our nickel comes from Canada.

Nickel steels are much used where great strength and toughness are required. In small quantities, up to about 5 per cent, nickel in steels increases the strength considerably without increasing its brittleness. When it was first produced, nickel steel was called "meteor steel"

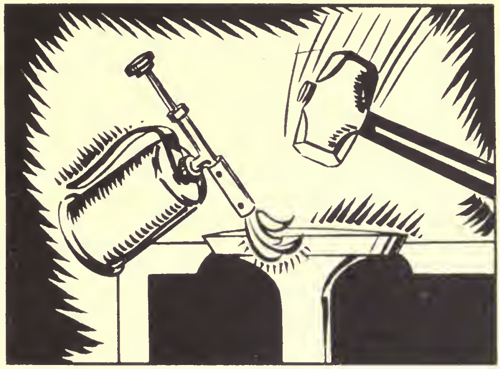


because it had almost the same composition as meteors. Steel in which nickel is one of the principal alloys is much used for gears in the transmission and rear axle, piston pins, and steering gear parts.

Iron Flashes

Nickel, chromium, cadmium, zinc and copper are plated on steel to protect the surface from rust. The chromium plate may be only a few millionths of an inch thick when it is plated over copper and nickel.

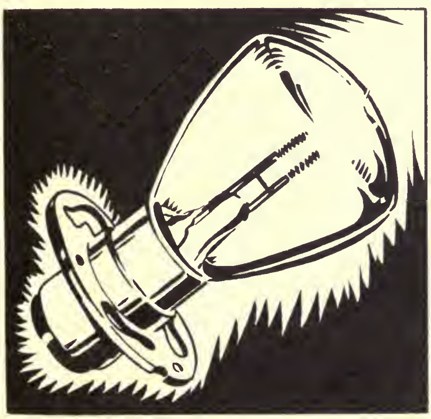
CHROMIUM



Chromium is a hard silvery-white metal used for plated parts on automobiles. The green color of emeralds is due to small quantities of chromium in the jewels. When added to steel in small quantities, either alone or with nickel, it produces a hard strong wear resistant metal. Gears and axles are often made of chrome-nickel steel because of its great strength. When alloyed with vanadium a fine grained steel results which is also used for gears and other highly stressed parts.

When silicon and chromium in large amounts are used, a heat and corrosion resisting steel results. Exhaust and intake valves, which operate at red hot temperatures, are often made of silicon-chromium steels. When about $^1/_5$ of the steel is made up of chromium, stainless steel is the result.

TUNGSTEN



Tungsten is a hard metal with the appearance of lustrous steel. It melts at a very high temperature, over 6000 degrees F. It is one of the strongest of all the metals with a strength in pull of almost 300 tons per square inch. Tungsten is familiar to all of us as the filament of electric light bulbs.

When tungsten, chromium, vanadium, molybdenum or manganese are added to steel in the

Iron Flashes

Chromium steels with about one per cent carbon are used for files and ploughs because of their hardness.

proper amounts, a hard cutting steel is produced. This is called "High Speed Steel" because it can be used to machine metals at a high cutting speed. Probably "high speed steels" have done more to make the large scale production of automobiles possible than any other metallurgical development. These tool steels retain their hardness even when at a red heat.

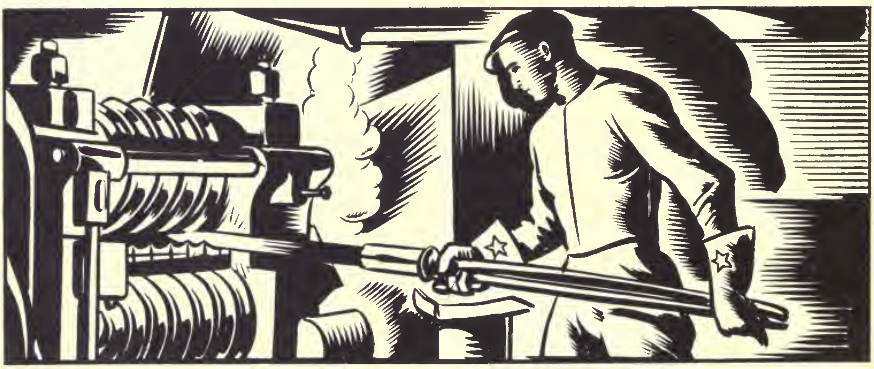
MOLYBDENUM AND VANADIUM

Molybdenum is a hard silvery-white metal. It is used alone or with chromium and nickel. It confers toughness and higher strength upon the steel. With nickel it is used extensively in steels for transmission and rear axle gears.

Vanadium is the hardest of all the metals and is more abundant than nickel, zinc, copper or lead in the earth's crust. Vanadium has been found to exist on the sun. It was discovered in Sweden and named after the goddess Vanadin. It is much used with chromium to make chrome-vanadium steel. Chrome-vanadium steels are used for leaf springs, transmission and rear axle gears and steering gear parts.

PRODUCTION MEN TAKE A HAND

We have followed the iron ore from the mine through the



Iron Flashes

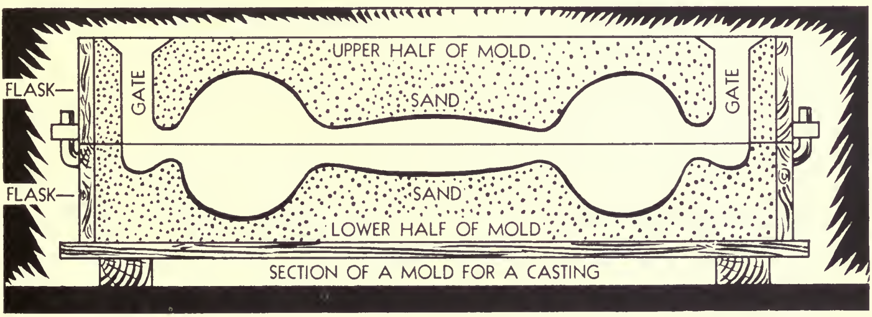
One out of eight people gainfully employed in the U. S. works directly or indirectly in the automobile industry.

blast furnace and steel mill. We have seen how the additions of small quantities of other materials affect the metal. However, most of the work is yet to be done in making a finished automobile.

The automobile factories obtain the steel in the rough form of bars, strips, rods, tubes, plates and sheets. Pig iron is obtained directly from the blast furnaces to make cast iron and malleable iron parts. The skilled mechanics, tool designers, metallurgists and production men take up the materials where the iron and steel men left off and, by various processes, produce the automobile. It might be interesting to follow a few typical pieces through the various operations in the factory.

LIQUID IRON IN MOLDS OF SAND

To make a number of intricately shaped hollow parts, cast iron is used. The pig iron from the blast furnace along with scrap steel and

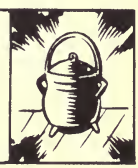


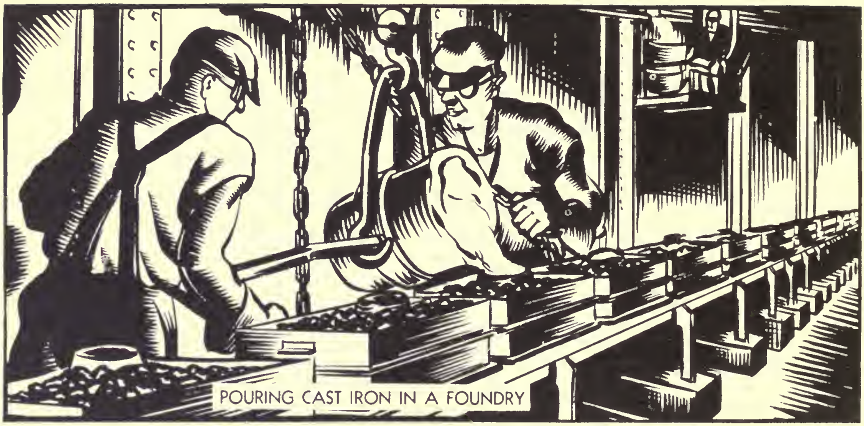
cast iron are re-melted in another furnace called a cupola. Its operation is similar to that of the blast furnace. Alternate layers of iron, flux and coke are charged into the furnace at the top and molten iron collects in a yellow pool at the bottom.

To make a casting it is first necessary to have a pattern made of wood or metal in the shape which we wish to cast. Suppose we wanted

Iron Flashes

The first iron casting made in the United States was an iron pot.

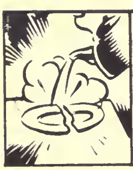



POURING CAST IRON IN A FOUNDRY

to make a solid cast iron dumb-bell. We would first make a pattern of the dumb-bell in two halves. To make the mold, one half of the pattern is placed flat side down on a board and a loose fitting box called a flask, open at the top and bottom, placed around it. There must be several inches of space between the pattern and sides of the flask. Damp sand is then firmly pressed around the pattern to fill the space between the pattern and flask sides. The whole box, pattern and sand are now turned upside down and dusted with a dry material to keep the two halves from sticking. The upper half of the pattern and flask are now placed over the lower half. In addition, a pattern of a gate to leave an opening for pouring the metal is placed in position. Sand is now rammed in as before. The top of the flask is then taken off and the patterns and gate are carefully removed. The top is then placed back on the bottom and we have a mold, as shown in the illustration, with a hollow in the center in the shape of the original pattern.

The molten cast iron is now poured into the mold to fill the space left by the pattern. The iron solidifies as it cools and the sand can be broken away, leaving a duplicate of the pattern which we started with.

The process of casting is similar to making jelly in molds. The hot



Iron Flashes

Some metals, when plunged into cold water, will crack just as a glass dish cracks when cold water is poured into it while the dish is hot. Pouring cold water into a hot engine may crack the cylinder head or block.

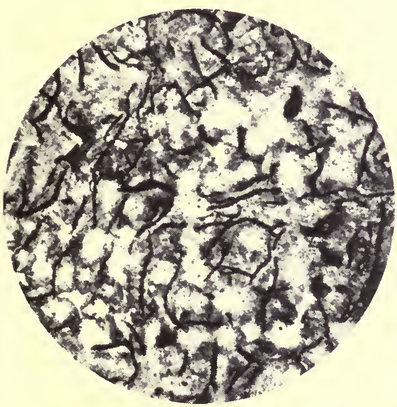
liquid jelly is poured into a mold of the shape desired. When it is cooled and is taken out, it has the shape of the mold.

Cast iron is low in cost and wears well, but is very brittle and cannot be hammered or formed when it is cold. It is used for parts where strength is not a major requirement. The automobile engine cylinder block, cylinder head, manifolds, water pump case, brake drums, flywheel, pistons, piston rings, and many small parts may be made of cast iron. A small amount of nickel or chromium is sometimes added to cast iron for the cylinder block to increase the wearing qualities of the cylinder bores. After the parts are cast they are machined to the final size by much the same methods as are used in machining steel.

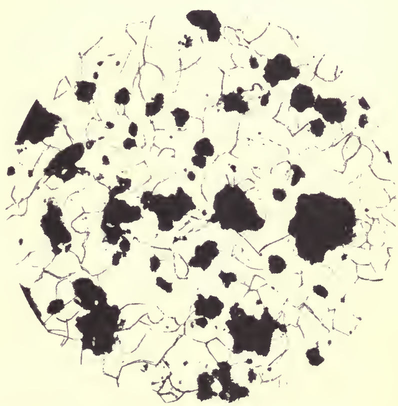
MALLEABLE IRON

We have seen that cast iron, which usually contains 4 per cent carbon, is very brittle and will not withstand hammering or cold forming. Where greater strength is required, malleable iron is used. Malleable means capable of being hammered or rolled without breaking.

CAST IRON



MALLEABLE IRON



MAGNIFIED 100 DIAMETERS

Iron Flashes

Cast iron shrinks during cooling ⅛ of an inch per foot of length, width and thickness.

Malleable iron is made from cast irons of a special composition. The castings are made in the same manner as when ordinary cast iron is used. After the casting has been taken out of the mold it is given a special heat treatment which completely changes its characteristics. The castings are packed in iron drums and heated in a furnace to about 1700 degrees F., which is a yellow heat. The castings are kept at this heat for a long time, after which they are slowly cooled. This treatment, which takes from two and a half days to a week, is called annealing.

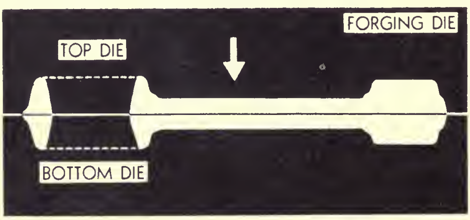
When they are removed from the furnace the castings look the same, yet a tremendous change has taken place inside. When the castings went into the furnace they were so hard and so brittle they could easily be broken with a hammer. When they come out, they will withstand a great deal of hammering and the metal is so soft that it will bend almost double before breaking.

Malleable iron is used for parts of the automobile where strength is required of complicated parts which must be cast. Wheel hubs, differential parts, clutch and brake pedals, bearing caps and spring hangers may be made of malleable iron castings.

YOU SHOULD HAMMER YOUR IRON WHILE IT IS GLOWING HOT

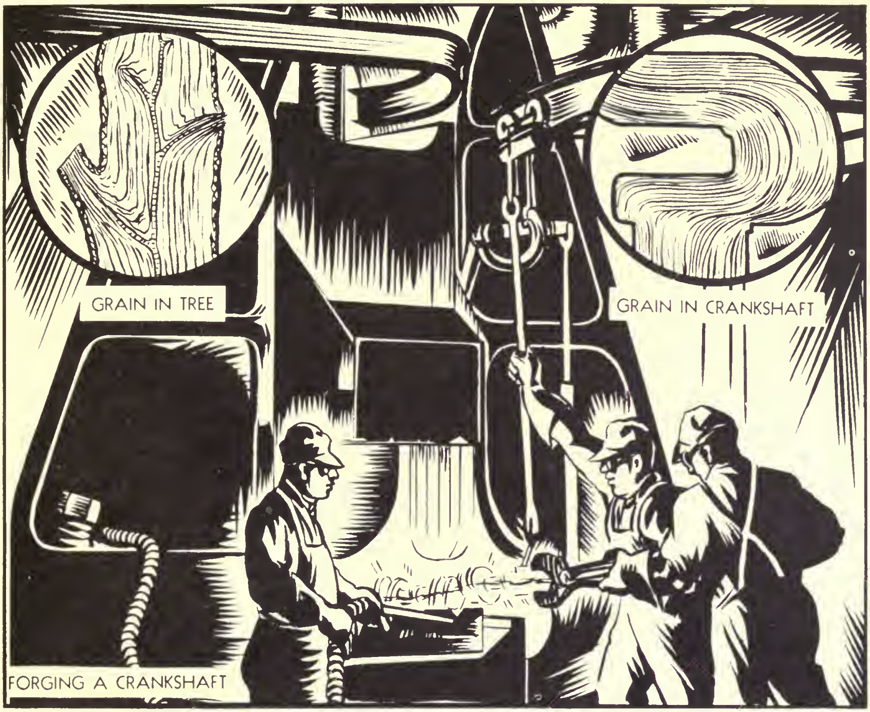
—PUBLIUS SYRUS

Forging is the process of forming steel by a hammer blow or a heavy pressure. Forging presses are made in sizes up to 6,000 tons. Steam hammers are usually used in forging operations, although hammers may also be driven by an electric motor or air. The method used to form steel parts by forging is similar to the method used by the blacksmith in making a horseshoe. Hot metal is hammered to the shape of the shoe on the anvil.



Iron Flashes

The earliest method of forming iron was probably forging by hand.



To make a connecting rod, a bar of steel of the right size is heated to a white heat in a furnace next to the hammer. The face of the hammer is shaped like the outside of the connecting rod. In some respects it is similar to the mold used in casting iron except that here the mold is of hard steel. In casting iron the mold was filled with molten metal. In forging, the white hot bar is squeezed between an upper and lower mold, or die, as they are called in forging practice, to fill the mold. The sharp hammer blow is necessary to squeeze the hot metal into the dies. The connecting rod dies will be made so that half of the shape is in the top and half in the bottom die.

Many automobile parts are forged. Crankshafts, camshafts, gear blanks, connecting rods, rocker arms, valves, steering gear parts, universal joint parts, rear axle parts, ball bearings, roller bearings and

Iron Flashes

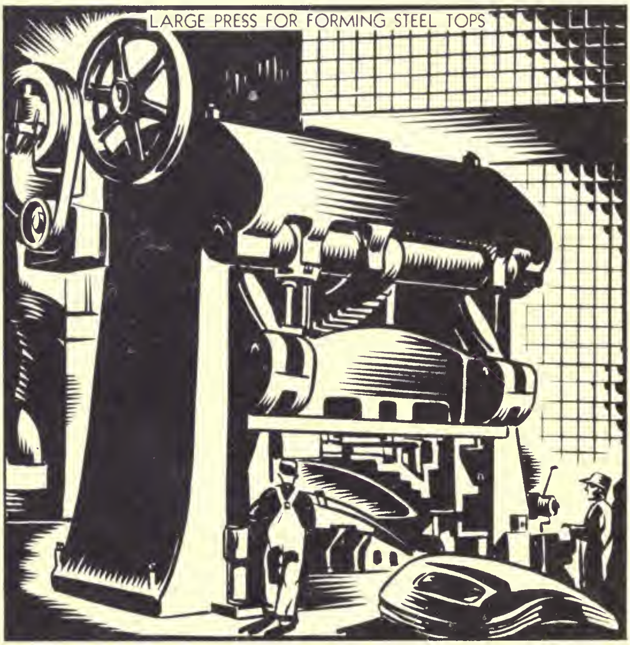
The chain placed across the Hudson River in 1812 weighed 186 tons and was forged at an early iron works near by.

many small parts are forgings. Forgings are usually machined before they are used.

An interesting fact about steel forgings is that they have grain lines just like a tree. The illustration shows the lines in a crankshaft compared to the grain in a small tree with a branch out one side.

PRESSES

Still another typical process of shaping steel into automobile parts is to form in presses. Parts, all the way from the smallest washer up to an entire steel automobile body top, can be made in presses. These presses vary all the way from a very small size up to the four-story high giants of 750 tons capacity. The process is, in some respects, similar to forging except that thin metal is used and it is formed cold.


LARGE PRESS FOR FORMING STEEL TOPS

To make a stamping, a set of dies is made in the shape of the part. The lower die is stationary and the upper one moves down over it. The metal is squeezed between the dies and comes out of the press in the shape of the finished part.

Many types of press work are done. Forming, piercing, bending and punching can all be done on a

Iron Flashes

Sheet steel for press work is soft and ductile, and contains very little carbon.

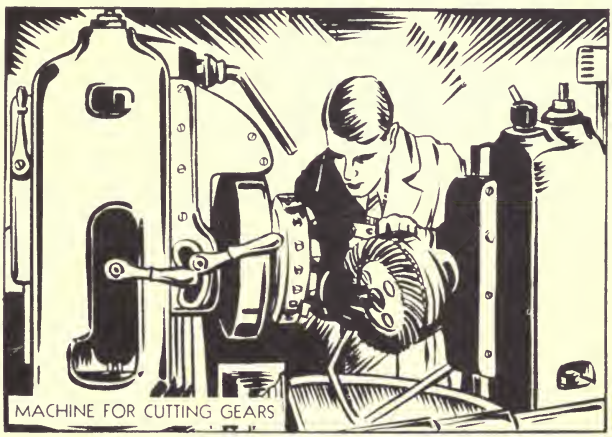
press. Sometimes a die is made to do several operations at once. Sheet metal is fed into the press and the complete part comes out. Other parts require several operations.

Press work makes strong, light, low cost parts. There are thousands of parts on your automobile made on presses of one type or another. Fenders, gasoline tanks, body parts, hoods, fans, frames, rear axle housings, steel wheels, and crankcases are some of the major parts made on presses. Many smaller parts such as washers, covers, headlight parts, tail light cases, instrument parts and dust shields are made in small presses.

MACHINE TOOLS

There are many types of machine tools for cutting steel and iron parts into the form desired. Lathes, milling machines, screw machines, grinders, broaches, drill presses, planers, shapers and dozens of special types of machines are used in making automobile parts. Each part and each job requires special tools and special machines. Sometimes a single piece will go through a number of machines, each doing one operation.

Forgings, castings, press work and bar, rod or strip steel are machined to make the finished part. Many machines are automatic and steel bars fed into one end come out finished parts at the other. Other machines require much skilled operation by trained machinists. All machines must be set up, and the special tools and fixtures made, by highly experienced tool



MACHINE FOR CUTTING GEARS

Iron Flashes

Almost a fourth of the metal working equipment in all the factories in the United States is used by the automotive industry.

makers. It would be impossible in this booklet to explain all the methods of machining metals.

Round parts are made on lathes, screw machines and turret lathes. Flat surfaces are cut on planers, shapers and milling machines. Milling machines, broaches, and special machinery are used for irregular shapes and holes. Drill presses are used for round holes. Special gear cutting machinery is used for making the various gears used in the automobile. Many parts are given the final finish by grinding. Each factory has thousands of machine tools of all types.

It is the machine tool which has lightened man's work and made it possible to produce automobiles in the reach of the greatest number of us. Over five million persons, or one out of every eight of those employed, are employed directly and indirectly in the automobile industry. Work for these men is made possible by the advance in machine tools.

WELDING

Welding is the term applied to the joining together of two pieces of steel, usually by melting the joints. Many parts of the automobile are

WELDING A FENDER

Iron Flashes

The blacksmith welds by heating the metal to a white hot temperature and pounding the joint together.

welded. Welding can be done by many methods. The most necessary thing is a method of producing a high temperature. The two most common methods are acetylene welding and electric welding.

For joining the panels on the automobile body and for making many smaller parts, electric welding is used. Even the thick sections of the rear axle housing are joined by this method. We know that if two wires on our house circuit are brought together we get a blinding flash and the wires are melted together. We therefore take every precaution that this kind of a "short" does not occur, since it not only burns out the fuses but is dangerous as well. However, welding machines can be built which use the right voltage and current so that parts can be melted at their joints and welded together.

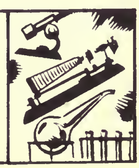
In the other method, acetylene welding, the joints are melted by an intensely hot flame produced by the burning of oxygen and acetylene gas. This method is not much used in the manufacture of automobiles, but is extremely valuable in the repair shops.

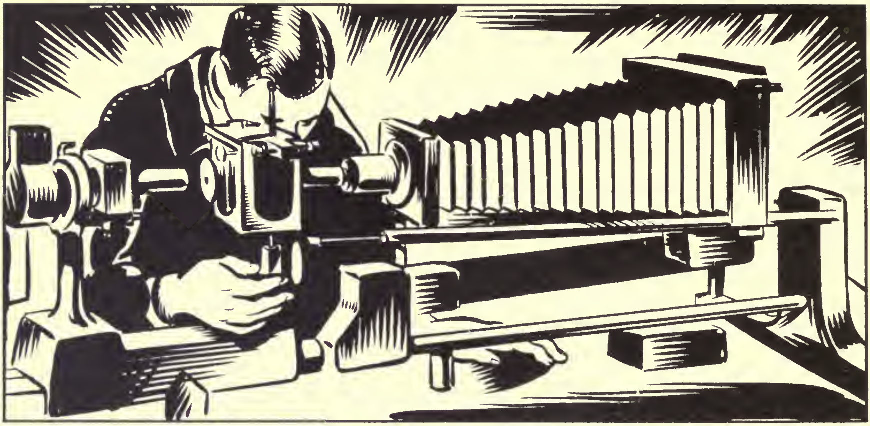
"FINGER PRINTS" OF STEEL

Heating and cooling can make large changes in the strength, hardness, brittleness and wearing qualities of iron and steel. Steel or iron is made up of fine microscopic crystals of iron, carbon and other alloying elements. Heat treatment is just a method of controlling the crystalline structure to give the desired properties. A piece of steel with a uniform fine grain is tougher than a piece with a large grain. The metallurgist uses a microscope to examine the crystals. A sample of the steel is ground and highly polished to give a smooth, even surface. It is dipped in dilute acid to show up the crystalline structure of the metal. Placed under a microscope and magnified from 100 to 1000 times, the formation of the crystals in the specimen classifies the steel to the metallurgist. These are really the "finger prints" of

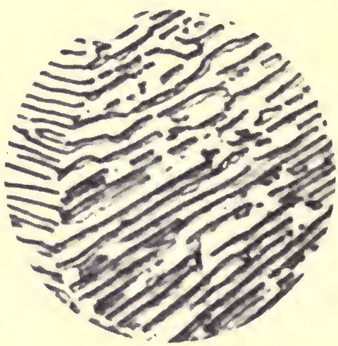
Iron Flashes

Metallurgists also use the spectroscope, X-ray, and chemical laboratories to study the internal structure and composition of steel.





the metal and identify the metal just as human finger prints identify a person. These "finger prints" are called photo-micro-



graphs. The illustrations show the structure of a number of different types of steels with the heat treatments described hereafter.

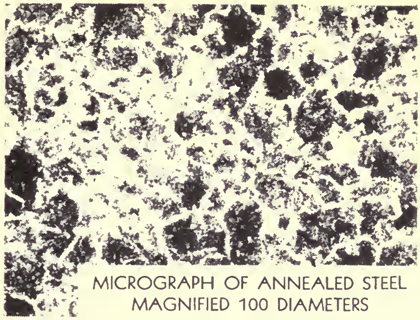
ANNEALING

Annealing is a process in which the metal is heated high enough to soften it and then slowly cooled. This relieves strains set up within

Iron Flashes

The Romans were familiar with hardening steel both by quenching it in water and in oil.

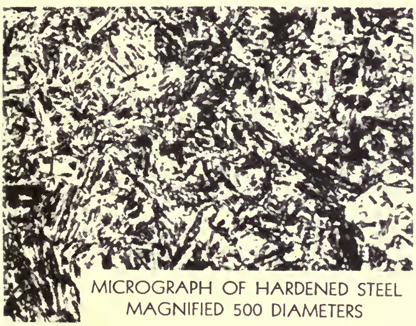
the metal by other treatments, makes the metal soft and ductile, alters the toughness or refines the grain structure. Either steel or cast iron can be annealed.


MICROGRAPH OF ANNEALED STEEL MAGNIFIED 100 DIAMETERS

We are all probably familiar with annealing. Tools, such as a saw or plane, which have gone through a fire, will no longer cut. This is because they have been heated to a high enough temperature and cooled slowly enough to anneal the steel and make it soft.

HARDENING STEEL

Steel is hardened by heating it to a high temperature and suddenly cooling it by plunging into water, salt brine or oil. Steels are hardened to give them a good cutting edge, a good wearing surface, or high strength. Sudden cooling of the steel changes the crystalline structure into a hard, brittle form.


MICROGRAPH OF HARDENED STEEL MAGNIFIED 500 DIAMETERS

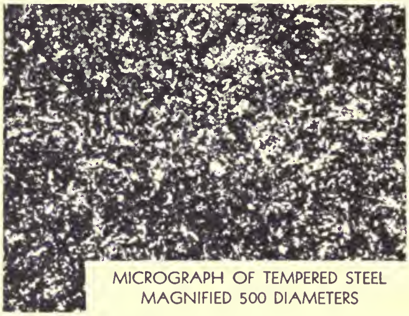
The photomicrograph shows the crystalline structure of a hardened steel. The piston pin, valve springs, leaf springs, coil springs, valve tappets, camshafts, crankshafts, gears, steering gear parts and connecting rods and many other parts are hardened to give strength or resistance to wear. Many of these parts are given other heat treatments such as annealing, carburizing and tempering. These treatments are described herein.

Iron Flashes

The rapid cooling during hardening sometimes sets up such high strains inside the metal that the steel flies into pieces.

TEMPERING

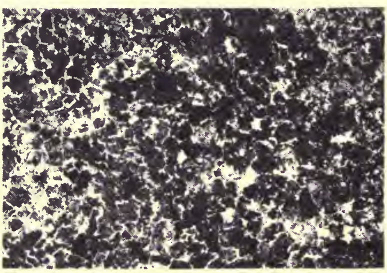
Tempering is the process of obtaining the exact hardness, strength and ductility of steel which is necessary for the work it is to do. After quenching, the metal is reheated to the desired temperature to give it the correct combination of toughness and hardness which its use demands.

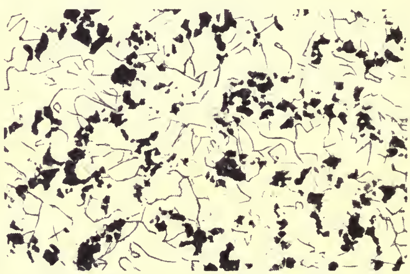

MICROGRAPH OF TEMPERED STEEL
MAGNIFIED 500 DIAMETERS

Crankshafts, which must be hard enough to withstand wear at the bearing surfaces, yet tough enough to withstand the explosion and other forces, are tempered steel. Connecting rods, valve and leaf springs and transmission gears are likewise quenched and tempered.

CARBURIZING AND CASE HARDENING

In some instances, it is necessary to have a glass-hard surface to resist wear and a tough center to give strength. This can be obtained with many steels by a process called case hardening. We have seen that the higher the carbon content of steel, the greater its hardness. Where a hard wearing surface is required, the surface is made of a high carbon content by carburizing.

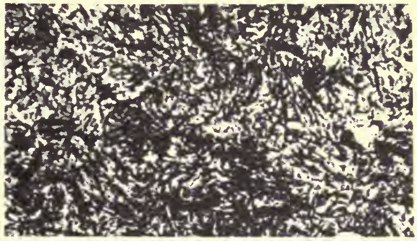

MICROGRAPH OF CASE OF CARBURIZED STEEL
MAGNIFIED 100 DIAMETERS


MICROGRAPH OF CORE OF CARBURIZED STEEL
MAGNIFIED 100 DIAMETERS

Iron Flashes

The deadly poison, sodium cyanide, is sometimes used to carburize steel.

MICROGRAPH OF CASE OF CASE HARDENED STEEL
MAGNIFIED 500 DIAMETERS



MICROGRAPH OF CORE OF CASE HARDENED STEEL
MAGNIFIED 500 DIAMETERS

To carburize a part, it is packed in a box and surrounded with carbon. The box full of parts is then heated to a yellow heat in an oven. The carbon may be in the form of wood or bone charcoal, charred leather or even sugar. Sometimes various chemicals are used. The steel parts absorb some of the carbon at the surface but the center remains unchanged. To case-harden the parts, they are quenched in water, brine or oil to harden the surface.

CASE HARDENED GEAR TOOTH

The difference in the outside and inside can be seen without the aid of the microscope in the fractured piece. The carburized surface is a different texture than the tough interior. The illustration shows the further difference which the microscope reveals. Rear axle gears, camshafts, transmission gears, steering gear parts and many other parts are case-hardened.

MEN

We have examined various means of forming iron and steel and machining finished parts. We have seen that many special types of steels are used for different parts and that heat treatments are used to bring out the right properties. In the automobile factory each piece of the automobile flows from process to process in a smooth, orderly manner. The machines are arranged so that the parts can move from

Iron Flashes

When it is not desired to carburize all of the surface of the metal, the part which is to remain soft is copper plated.

the raw material stage to the finished part with the least movement and effort.

Conveyors are used to carry the parts along from machine to machine and to lighten the back-breaking labor formerly necessary in all factories. The cylinder block is started at one end of a conveyor line. As it moves along, a group of workmen add parts until at the end of the line, we have a finished engine. Transmissions, rear axles and bodies are put together on sub-assembly lines. These sub-assemblies are carried by other conveyors to the main assembly line where workmen put them together to make the complete car. A single factory may turn out as many as 5000 complete automobiles every day. Each of the thousands of parts are produced on time and delivered to the right spot. Each individual part must be made of the right material, given the correct heat treatment and be made to an accuracy measured by thousandths of an inch.

To do all these things requires the co-operation of thousands of men using every type of machine which other men have conceived and

Iron Flashes

Pure iron is not rusted by exposure to pure dry air at ordinary temperatures.
Iron increases in volume from 10 to 20 times when it rusts.

built. Engineers, tool and die designers, tool makers, metallurgists, electricians, machine operators of many types, chemists, and skilled workmen each has his specific part of the work. Each man, doing his own work, and responsible for one job, makes it possible for all of us to enjoy the benefits of the motor car. When it rolls off the end of the assembly line, even the smallest car has the equivalent of almost three months of a man's labor. New wealth has been created largely out of iron rust. The country and all its people are richer and are ultimately benefited by the creation of a usable article from the ore of the earth.

The Story Below is Reprinted from a Customer Research Bulletin.

Paul deKruif, in his delightful book "SEVEN IRON MEN" traces the genesis of the giant automobile industry, not back to Duryea, nor to Olds, nor to Haynes, but to the Merritt boys who, after prospecting for gold in the wilds of the Duluth-Superior district for several generations, finally stumbled onto the great Mesabi Range.

Here lay the ingredients that were destined to feed the great assembly lines of the automobile industry—that were to usher in a new era of mechanical products at low cost, and make America the industrial capital of the world.

It had taken three generations of rigorous prospecting by the Merritt frontiersmen—three generations of hard going.

And it took almost another generation to break down traditions and get something done about it.

Here was the rich ore in the form of iron oxide filling an entire valley—laying right out on top of the ground—assaying 64 per cent pure iron. Buicks, Cadillacs, Oldsmobiles, Chevrolets and Pontiacs in the amorphous form—stretching as far as the eye could see.

Iron Flashes

When the Spaniards invaded Mexico, they found the Aztecs possessed knives of iron which they valued higher than gold.

The Merritts didn't know much about iron so they imported an expert —a real practical Cornishman—a mining engineer.

The Cornishman knew his business—but an iron mine off of a railroad track was something new in his experience. After grumbling about having to go through the wilds to get to the place—he looked it over, knitted his brow and uttered an oath—"What's the matter," asked one of the Merritts —"It's real iron ore, isn't it?"

"Yes," answered the Cornishman "I guess IT'S IRON ALL RIGHT, but how are you going to mine it? It's too much out in the open. It's got no hanging wall—and where's your foot wall—tell me that?"

"—and anyway the stuff's too loose and fluffy—you'll never be able to sink a shaft into it—the sides will cave in!"

The Merritts went into a huddle. Then they timidly asked, "Why should you have to sink a shaft—why not just dig it right up with shovels?"

Iron Flashes

Oil, gas or electric furnaces are used for heating parts to be hardened, annealed, tempered or carburized.

The finer sensibilities of the Cornishman were deeply offended—he was horrified! He told the prospectors in no uncertain terms that even in the secluded wilds of the Mesabi he would not—could not cast aside the ethics and traditions of his time-honored profession—under no circumstances would he be a party to any such unorthodox procedure—"no shaft—no mining"—was his parting injunction. Then he got on his donkey and started back on the 100-mile jaunt to Duluth.

But the project was not entirely abandoned—and some people finally became interested who, although lacking in traditional background, managed to get the 64 per cent ore out of the valley—onto a train—into a boat—across the lakes and down the throats of the yawning Pittsburgh Bessemers—and at about the same price that it had formerly cost to elevate ore from the bowels of the earth.

Iron Flashes

The famous Damascus blades of the Middle Ages were made from steel imported from India.

OTHER BOOKLETS OF A SIMILAR NATURE

"POWER GOES TO WORK"

A simple explanation of the fundamentals of power transmission systems, portraying in some detail the power drives of the automobile, airplane, and ship. Many colored illustrations.

"A POWER PRIMER"

"A Power Primer" strips the internal combustion engine of its technical mysteries by presenting the simple elementary facts about engines in general use today—automobile, aircraft, and Diesel.

"CHEMISTRY AND WHEELS"

The fascinating story of the combustion of gasoline in an automobile engine, treated from the standpoint that the motor car is a chemical factory on wheels.

"ABC's OF HAND TOOLS"

A simple and informal text, together with cartoons and drawings, tells the right and wrong ways of handling and using the more common hand tools.

"OPTICS AND WHEELS"

A survey of the outstanding historical events in the development of artificial light, as well as the basic principles of optics as applied to automotive lighting problems.

ADDRESS

Department of Public Relations

GENERAL MOTORS

Detroit, Michigan

50M—11-49

LITHO IN U. S.

STEEL
1.5% CARBON

CAST IRON
2.5% CARBON

CAST IRON
3.0% CARBON

CAST IRON
4.0% CARBON